Age-Dependent Changes in the Histograms of ADC Values

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Target audience Neuroradiologists, Neuroscientists, Physicists

Purpose

Readout-segmented EPI (rs-EPI) sequences (1) allow the acquisition of diffusion weighted images with high spatial resolution. We applied rs-EPI sequences in clinical routine examinations with an excellent image quality and evaluated whether apparent diffusion coefficient (ADC) histograms can be used for an observation of age-dependent brain volume losses.

Methods

All measurements were performed with a conventional 3T MR whole-body scanner Skyra (Siemens Erlangen, Germany) equipped with a 20-channel head coil as part of the standard routine examination of patients with neuroradiological report requests. In 783 patient examinations, the diffusion weighted rs-EPI sequence was applied with identical measurement parameters: TR 6.3 s, TE 73 ms, b-values 0 and 1000 mm/s^2 (b0 and dw images), matrix 224*224, FOV 230 mm, sl 4 mm, 30 axial slices. Data were checked visually and data sets with brain lesions due to infarctions or tumors, with white matter lesions or large white matter defects, with artefacts or pathologically enlarged CSF spaces were excluded. After this, the remaining number of data-sets from patients was 550 (260 female, 290 male).

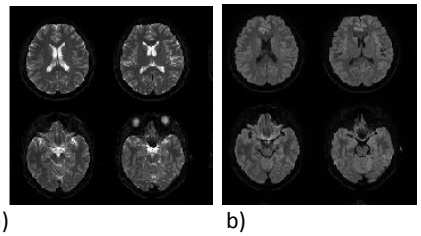
Postprocessing consisted only of a rescaling of singal intensties due to histogram evaluation of the dw-images. Noise pixels and pixels from the skull were excluded by applying a combined threshold derived from b0- and dw-images. For the remaining pixels, the ADC value was calculated and histograms of all ADC-values were evaluated for each patient. The histograms were normalized to the number of pixel exceeding the noise threshold. In the histograms, a characteristic ADC-value was selected (1.15 10^{-3} mm^2/s) and the numbers of pixels below and those above this value were counted. The number of pixels below the characteristic ADC-value were counted for different age and gender groups.

Results

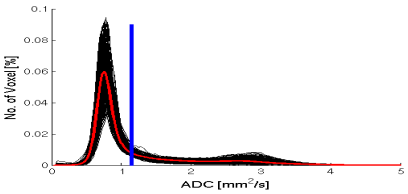
All ADC histograms had a similar shape (Fig. 1). The average histogram showed a clear peak for brain tissue for an ADC value of 0.75 10^{-3} mm^2/s and a tail of larger values corresponding to pixels containing CSF or a considerable partial volume contribution from CSF.
The value of the relative number of pixels in the brain compartment of each subject was marked as a point in Fig. 2 against the age of the patient. The diagram shows decreasing values of the relative contribution of brain tissue pixels with age. The slope is not constant, therefore, the marked points were fitted by a polynomial of degree 2. The fitted polynomial is shown in Fig. 5a. The equation of the polynomial is: $y = 82.5 \; -0.040\,x - 0.0030\,x^2$ (x: age). The evaluation was repeated for female and male patients separately. The results are shown in Fig. 3. The decline of the contribution of brain tissue pixels is slightly stronger for men. The fitted polynomials are $y_{female} = 82 - 0.105x - 0.0030x^2$, $y_{male} = 83.4 - 0.062x - 0.0031x^2$.

Discussion

In this study, b0 images and the dw images from a large patient cohort were used to calculate histograms of ADC values from the whole brain. Watanabe et al. (2) found in a similar approach age-related changes of the ADC peak value in these histograms. In this study, the histogram was used to discriminate signals from brain tissue and CSF. A decrease of pixels from brain tissue with increasing age could be observed. This corresponds to previously published results obaind with other methods, based on the analysis of T1-weighted 3-D measurements and avoxel-based morphometry analysis(3,4).



a) b)



c)

Fig. 1: Examples of b0 (a) and dw (b) images and histograms of ADC values from all patients (black), the average histogram (red) and the characteristic ADC-value(blue) (c).

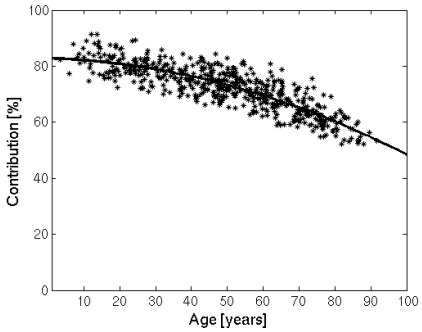


Fig. 2: . Integrals of ADC histograms in the range of low ADC value below the characteristic value in dependence of the age of the patients and the fitted polynomial for all data.

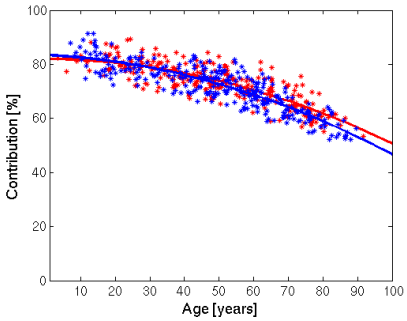


Fig. 3: . Integrals of ADC histograms in the range of low ADC value below the characteristic value in dependence of the age of the patients and the fitted polynomial for data from female (red) and male (blue) patients

Conclusion

The presented technique provides a simple possibility to examine the age dependence of MR signal intensities within the brain. The presented technique is applicable in the clinical environment. It uses data from a sequence which is often part of the standard diagnostic procedure, and no data segmentation or other data transformation apart from rescaling is necessary.

References

[1] Porter D, Müller, Proc Intl Soc Mag Reson Med 11(2004)442, [2]Watanabe M et al., Radiology 266(2013)575-582.
[3] Taki Y et al., Neurobiol Aging 25(2004) 25455-463 [4] Good CD, et al.,Neuroimage 14(2001)21-36.